Irrigation Energy Efficiency **BPA**

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A COMPARISON OF LOW PRESSURE CENTER PIVOT IRRIGATION SYSTEMS

Introduction

Center-pivot sprinkler irrigation is presently being used on about 1.2 million acres in the Pacific Northwest. This acreage is increasing as other types of sprinkler systems are converted to center pivots. As electric energy rates increase and labor becomes more scarce, there is more incentive to convert to low pressure center pivots. However, there are potential problems associated with low pressure systems of which the user should be aware, namely pressure regulation and potential runoff. (See the companion bulletin on reservoir tillage for controlling runoff.)

Types of Low Pressure Systems

Three basic types of low pressure systems are available.

1. Low pressure impact sprinklers use low pressure fixed-orifice nozzles with pressure regulators, or low pressure flow-control nozzles, and operate effectively at pressures of 25 to 40 psi (1 psi = 2.31 feet of water pressure).

2. Spray heads mounted on top of the center pivot lateral or on drop pipes or booms are most effective with pressures of 15-25 psi (Figure 1). Drops are used to lower the spray head elevation to reduce wind drift and spray evaporation, and booms are used to increase the effective spray pattern width and thus reduce application rates (Figures 2 and 3).

3. Furrow drops or bubblers are an extension of spray heads which drop the water directly onto the soil with a small diameter (1 to 3 feet) spray pattern (Figure 1). On cover crops such as hay and grain, bubblers are suspended about 3 feet above the soil with a close spacing (3 to 4 feet). On row crops the bubblers are usually aligned with alternate furrows. Pressures as low as 6 psi can be used at the nozzle which controls the flow. Basin or reservoir tillage is usually required with this system to prevent runoff.

Pressure Regulation

Effective pressure regulation is a necessity with low pressure systems, particularly on sloping lands. For example, an elevation difference of 35 feet is equivalent to 15 psi pressure change. Pressure regulators are used with individual sprinklers or spray heads to maintain a nearly constant pressure at the nozzle. Thus, the system can be designed with fixed-orifice nozzles without regard to pressure variations within the system. It is necessary to maintain a minimum pressure in the system about 2 psi greater than the nominal regulator pressure. Pressure regulators are available in outlet pressures of 6, 10, 15, 20, 25, 30, 40 and 50 psi. The 6-10 psi regulators are not recommended for use except on very low slopes. The currently available regulators will maintain flows within $\pm$ 5 percent with pressure variations of up to 80 psi. They are quite durable but can be damaged by pressure surges in the system. Pressure relief valves on the pivot lateral and/or a pressure control valve at the pivot supply can be used to protect the regulators.

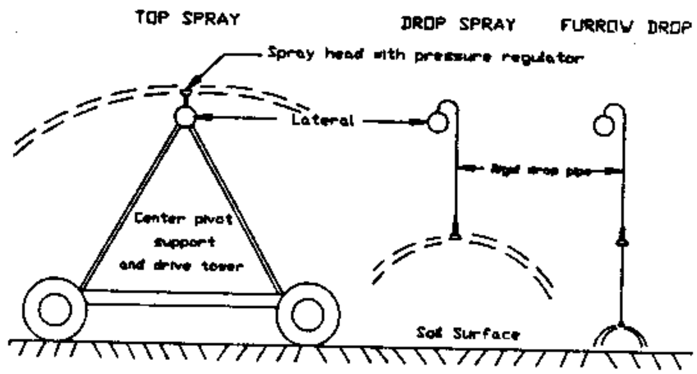

Figure 1. Three low pressure spray head configurations.

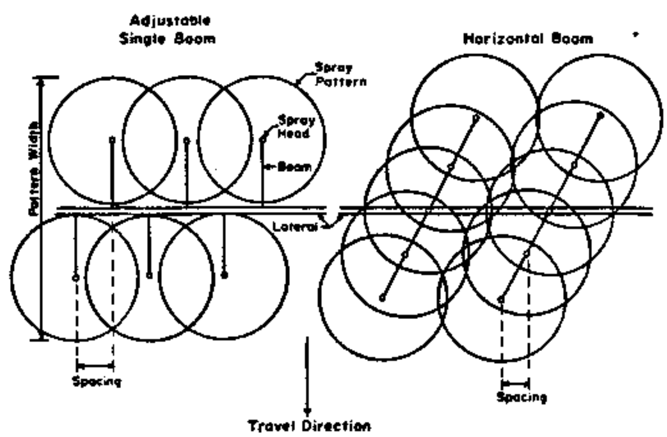

Figure 2. Top view of two types of spray boom systems.

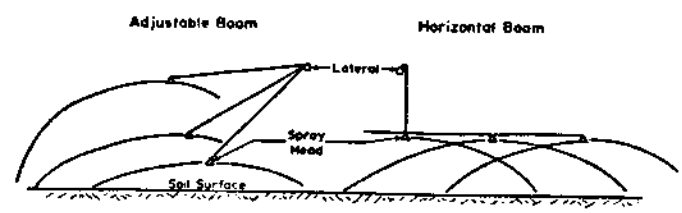

Figure 3. Elevation view of boom systems.

Application Rates

Water application rates under center pivots are a function of system capacity, system length, and type of sprinkler used. Typically, system capacity ranges from 5 to 9 gpm/acre (0.27 to 0.48 inches/day). The most common system length is about 1280 feet. The average application rate at a specified distance from the pivot is

$$A = .0139\ R\ G/W \tag{1}$$

where A is average application rate in inches/hour, R is distance from the pivot in feet, G is gross system capacity in gpm/acre, and W is the pattern width in feet (the diameter of the sprinkler spray pattern plus the effective width of the booms as shown in Figure 2). Table 1 contains pattern widths and application rates for several types of sprinklers with G=8 gpm/acre, and R=1250 feet.

Table 1. Pattern width and application rate for typical center pivot sprinkler, spray, and furrow bubbler systems.

Sprinkler Type	Pressure psi	Width (W) feet	App. Rate (A) in/hr
HP Impact	60	100	1.4
LP Impact	30	80	1.7
Hor. boom	15	70	2.0
Adj. boom	15	60	2.3
Spray	15	35	4.0
Bubbler	10	3	46.0

Figures 2 and 3 show how the boom systems increase the effective pattern width without increasing the pressure requirement for spray heads. The adjustable booms are used with individual heads, while the horizontal booms use several nozzles and are mounted at an angle to the lateral to maintain a constant effective nozzle spacing. Figure 3 shows an end view of the booms. With the adjustable booms, the nozzle offset distance from the lateral increases as the nozzle height is increased. The spray pattern width increases with elevation. Thus, from the standpoint of application rate and runoff (and uniformity), higher spray head elevations are desirable, especially when using adjustable booms.

Uniformity of Application

The drop size distribution and spray pattern of the 360-degree spray heads can be controlled by using various spray plate configurations and nozzle pressures. The 360-degree spray head consists of a base with 3/4-inch pipe threads, a removable nozzle (brass or plastic) and a spray plate support. The water jet from the nozzle impinges on the center of the symmetrical spray plate and produces a fan type spray pattern which is nearly symmetrical. Three main plate shapes are used, flat, concave, and convex. When the spray heads are inverted as on drops or booms, the smooth concave spray plates with 15 or 20 psi nozzle pressure produce the best combination of droplet sizes and pattern shapes.

The main factors affecting uniformity are spray head elevation, spacing, and nozzle pressure. The impact sprinklers and high elevation sprays consistently give uniformity coefficients (CU) of 0.93 to 0.96. The 6-foot elevation sprays give CU values nearly equal to the higher elevation spray heads. As the spray heads are lowered, the uniformity tends to decrease. At the 3 foot elevation and 5 to 6-foot spacings, the 10-psi spray heads give CU values of 0.92 to 0.95. At 3 foot elevation and 8 to 10 foot spacings, the CU decreases to about 0.85, which is the minimum acceptable uniformity.

Uniformity increases with spray head elevation, the largest increase occurring between 3 to 6 feet. Spray heads at elevations of 6 feet or higher have CU values above 0.9 over a wide range of spacings. CU increases with nozzle pressure with the largest increase occurring between 6 and 10 psi. At 15 psi or higher, the uniformity is consistently high over a wide range of spacings.

Under most conditions 10 psi is the minimum nozzle pressure, 6 feet is the minimum elevation, and 8 feet is the maximum spacing that should be used with spray heads to obtain acceptable uniformity. For nozzle pressures of 20 psi or more, spacing can be increased to 10 feet. It is important that the nozzle package be sized for the specific spacing used.

Spray Losses

The main factors affecting spray losses are spray head elevation, wind speed and nozzle pressure. The 3-foot elevation sprays consistently give spray losses less than 3 percent. The 6-foot elevation sprays have an average of about 5 percent and the sprays on top (12 to 15 feet) average about 10 percent loss. The impact sprinklers also average about 10 percent loss. The bubblers have essentially zero spray loss.

Wind speed has a large effect on spray loss. For example, the impact sprinklers may have losses of 5-7 percent at wind speeds under 5 mph, and losses of 10-18 percent at wind speeds of 5 to 10 mph. With smooth-plate spray heads, losses appear to increase significantly for pressures greater than 20 psi. These results indicate that the low elevation (6 feet or less) spray heads operating at pressures less than 20 psi can approach the efficiency of the furrow bubblers with respect to spray evaporation and wind drift loss.

Summary

The most serious potential problem with low pressure systems is the high application rates which tend to produce runoff. Reservoir tillage can greatly reduce runoff, particularly on row crops. The bubbler system eliminates spray losses but introduces other problems such as maintaining alignment with the furrows, and erosion of the furrow dikes. On sloping lands and medium textured (silt loam) soils, the most effective low pressure system appears to be a combination of spray drops on the inner half and spray booms on the outer half of the pivot lateral, with spray heads mounted between 6 to 8 feet above the soil. On corn, adjustable elevation drops or booms can be used.

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